



Garmin GPS for Accurate Topography

Innovation Spinoff from
Appalachian Region AOC Studies
January-April, 2010

2010 AOC Studies

- Random sample of permits with planned AOC reclamation:
 - Reflect latest SRA AOC policy
 - Phase 1 bond released portion available
- State-specific policy variations factored in (e.g., drainage, slope requirements)
- Compare topography (cross-sections the minimum):
 - Pre-mine
 - Approved reclamation plan
 - On-the-ground
- Post-mine topo from LiDAR ideal; otherwise site visits with measurement by clinometer, GPS, survey, etc.
- GPS preferred, but sub-meter requirement a problem



The GPS Problem

- Limited number of 3 sub-meter units (~\$3,000) available – 10 site visits necessary
 - Only 2 confident operators – neither available
 - Some offices “gun-shy” after bad post-processing experiences
- Alternatives?
 - Contract work – no \$, no time
 - Are less capable, user-friendly GPS units good enough for AOC studies?



Why Garmin?

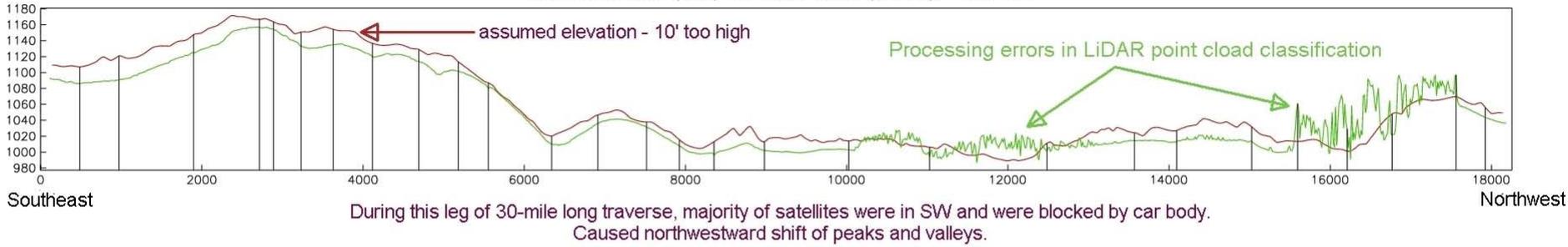
- eTrex Vista (~\$250) features:
 - WAAS
 - 24MB memory
 - Lightweight
 - One-hand operation
 - Rugged
 - Aneroid altimeter record correction**
 - 2 AA batteries
 - Easy to learn; easy to use
- Proven utility by OSM, PA, others since 2000
- 34 Vistas available due to TIPS' popular class; 17 in Pittsburgh
- Familiar and trusted by majority of OSM field/technical folk
- Over 350 people have received the training; 311 under TIPS

Concept

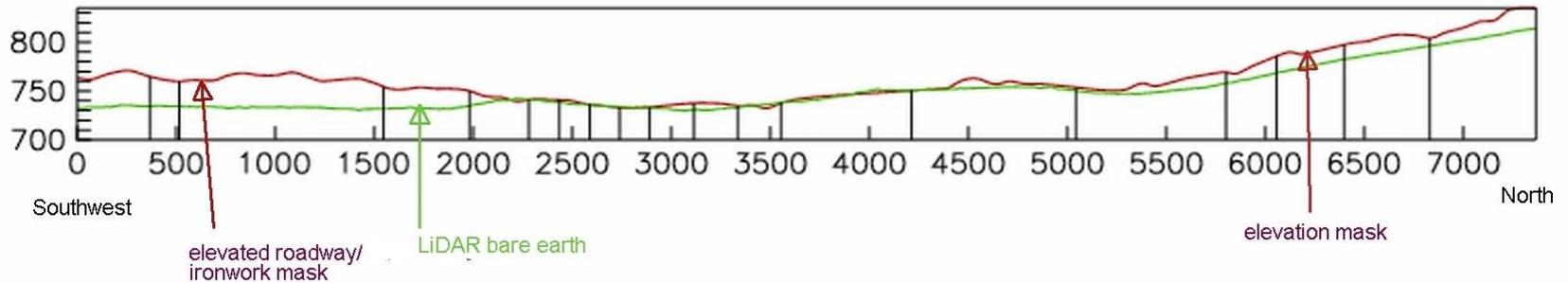
- 1/26/10, Mike Dunn, playing with old Garmin Vista, recorded every 1/100th mile on his dash driving to work.
- Plotted on cross-section with LiDAR topography, the 2,200 points rather faithfully followed the contour.
- Min Kim: “Wow! How well does it work in hilly terrain like the coalfields?”

Cranberry Traverse

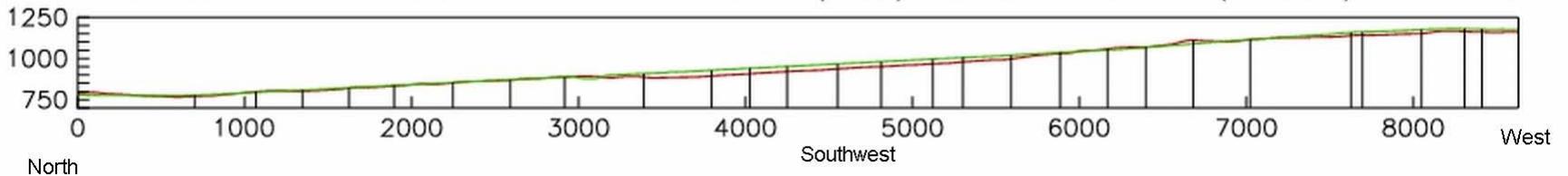
Garmin Altimeter (RED) vs. 2006 LiDAR (GREEN). 10X V.E.

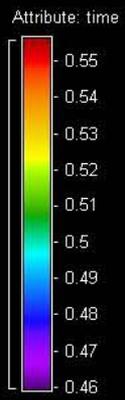


I-279 (East Street Valley) Garmin Altimeter (RED) vs. 2006 LiDAR (GREEN). 5X V.E.



Fort Pitt Tunnel to OSM Garmin Altimeter (RED) vs. 2006 LiDAR (GREEN). No V.E.



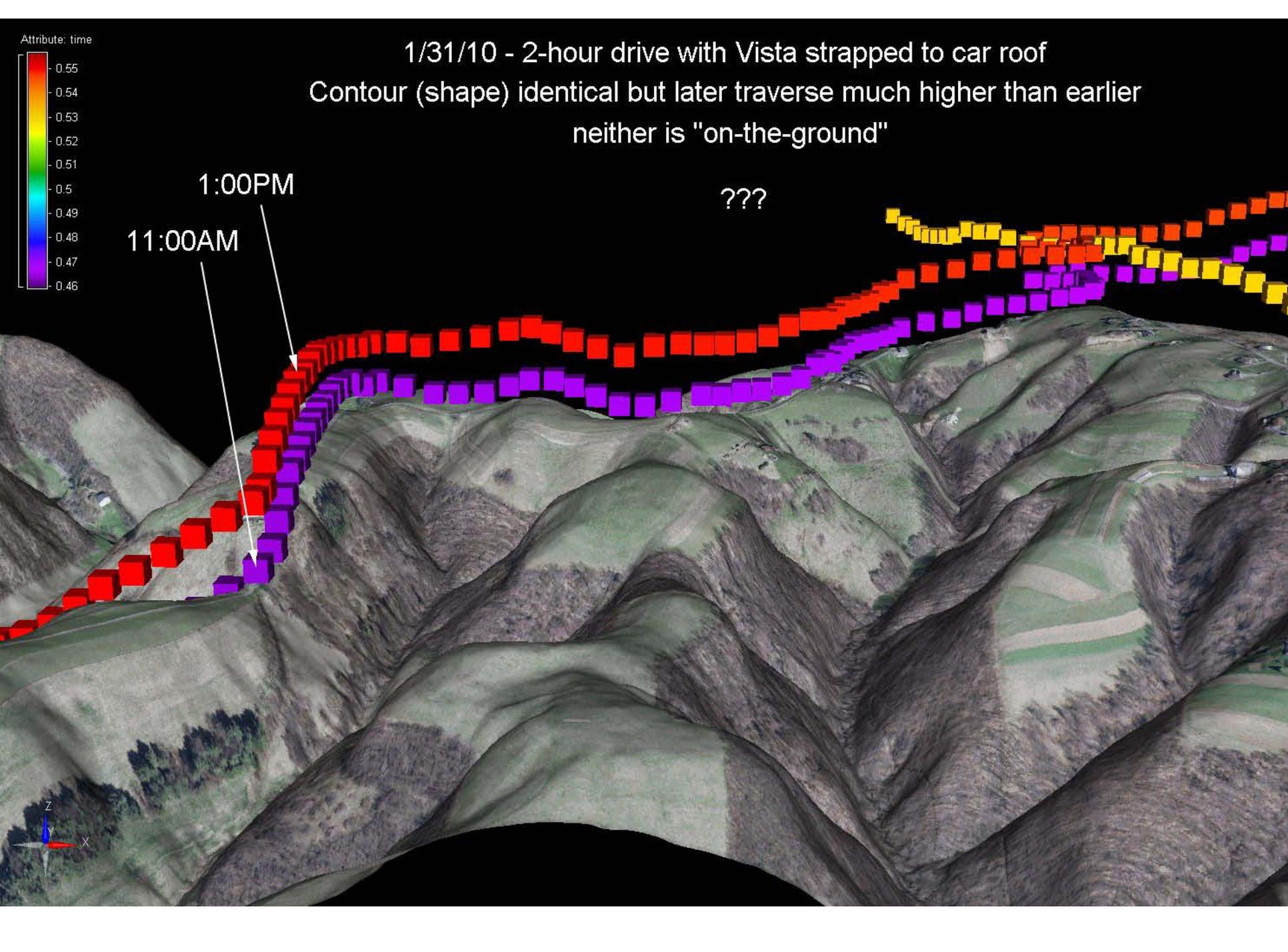


1/31/10 - 2-hour drive with Vista strapped to car roof
Contour (shape) identical but later traverse much higher than earlier
neither is "on-the-ground"

11:00AM

1:00PM

???



Concept/Gamble

- Figured out changes:
 - daily heating = less dense warmer air
 - air pressure drops = higher elevation
 - How to compensate for pressure change?
 - Repeatedly traverse known elevations, figure the correction, and distribute.
- Worst case, total failure.
- No study site more than 3 hours' drive if revisit needed to use different technology (*or figure out what went wrong and revisit with a fix*)

First Try

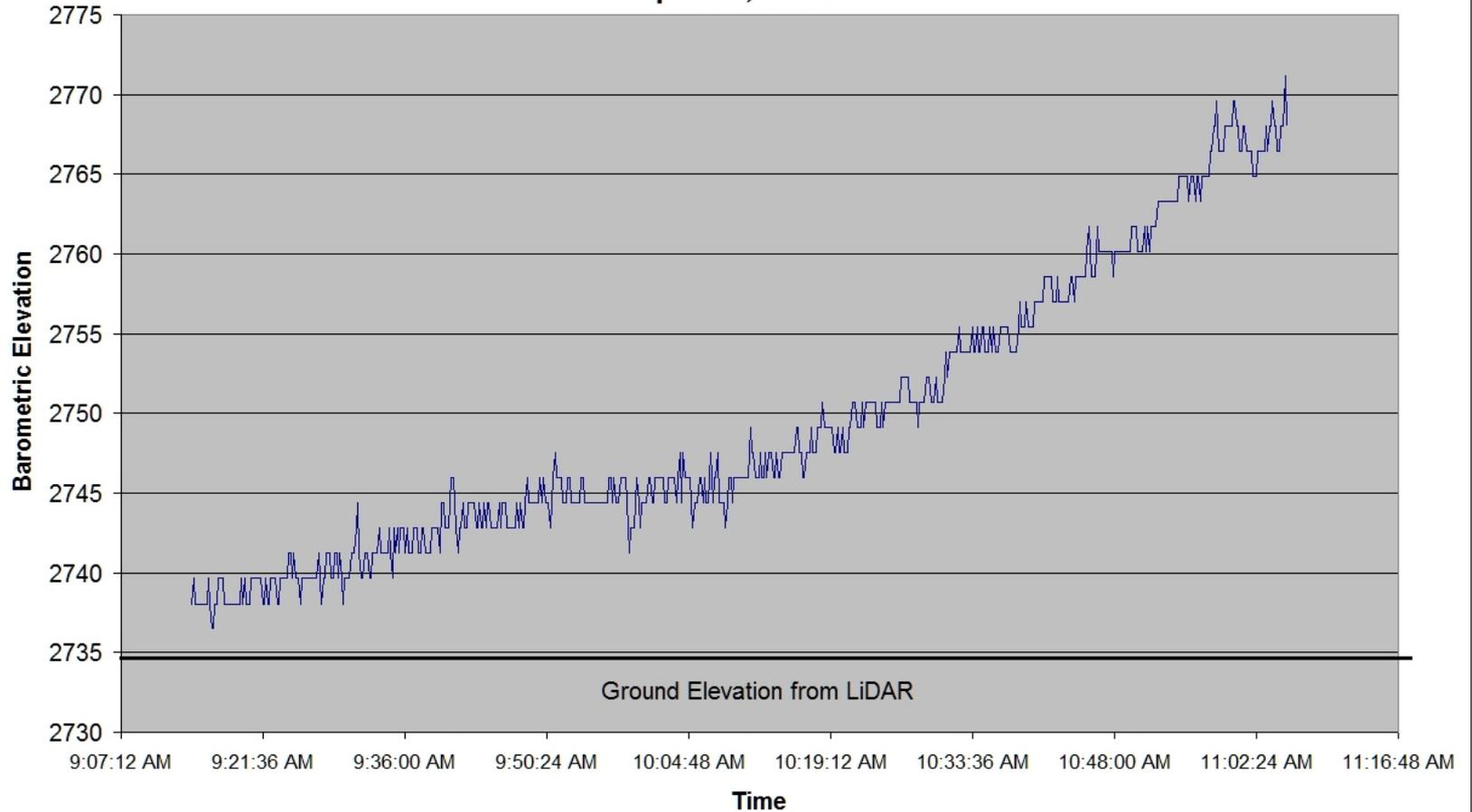
- 2/11/10:
 - MD area mine; 4' snow.
 - N-S traverse worked; Ken Eltschlager fell on E-W traverse and correction distribution became problematic.
 - MD contour site: short traverse (10 minutes)
 - global correction worked and Garmin traverse ~ LiDAR!

New Approach

- Minimum-
 - one base Garmin
 - one roving Garmin (2 is better!)
- Calibrated to same elevation and time; recording same interval (3 to 30 seconds)
- Pressure “drift” is distributed to all rovers using base unit time-of-day corrections
- Maryland area mine revisited 4/15/10 – astounding!

Maryland Area Mine, Base

April 15, 2010



Garmin Base Data

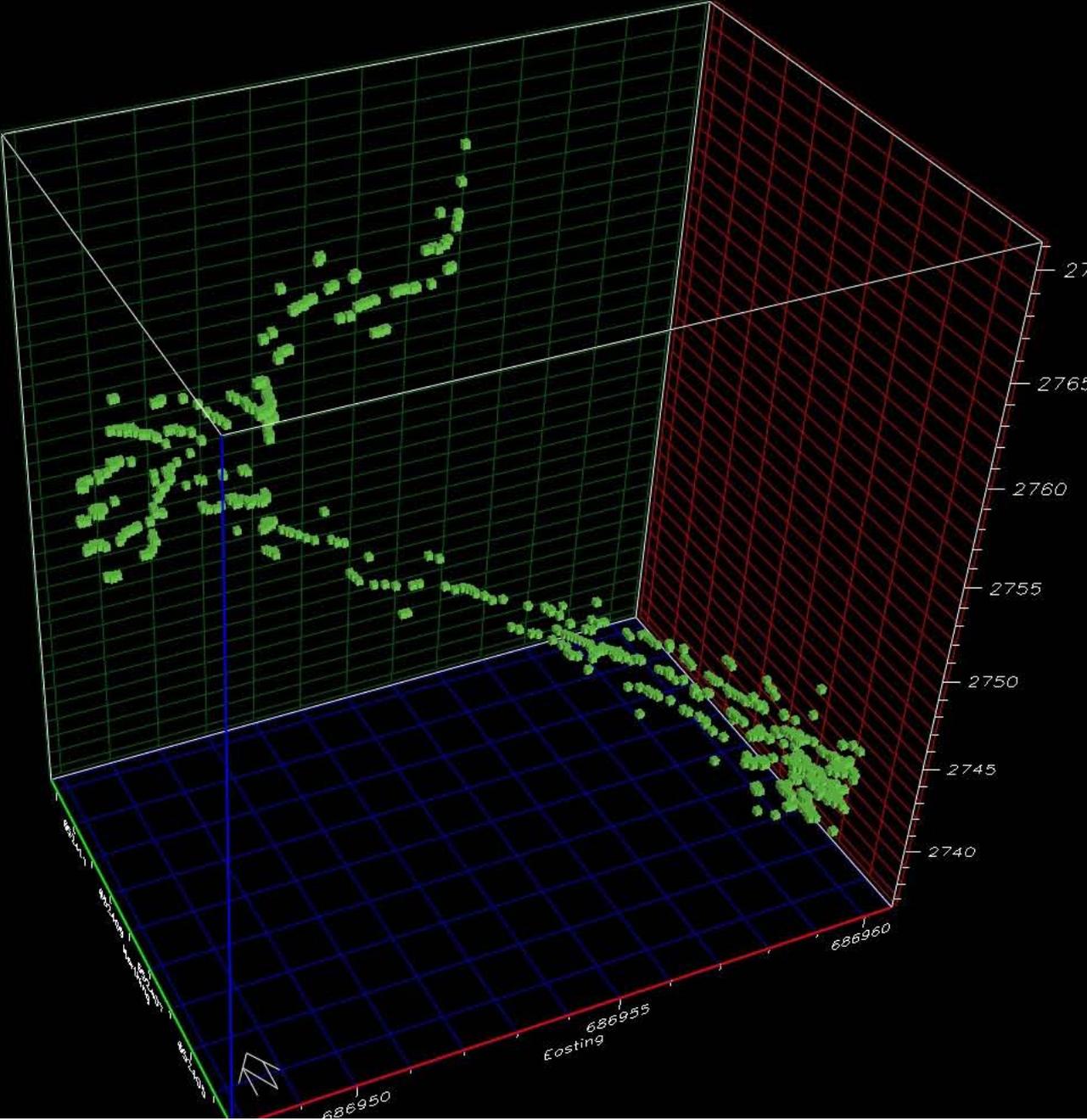
~ 90 minutes:

GPS Range =

13 feet X; 8 feet Y

Barometric Range =

34 feet Z

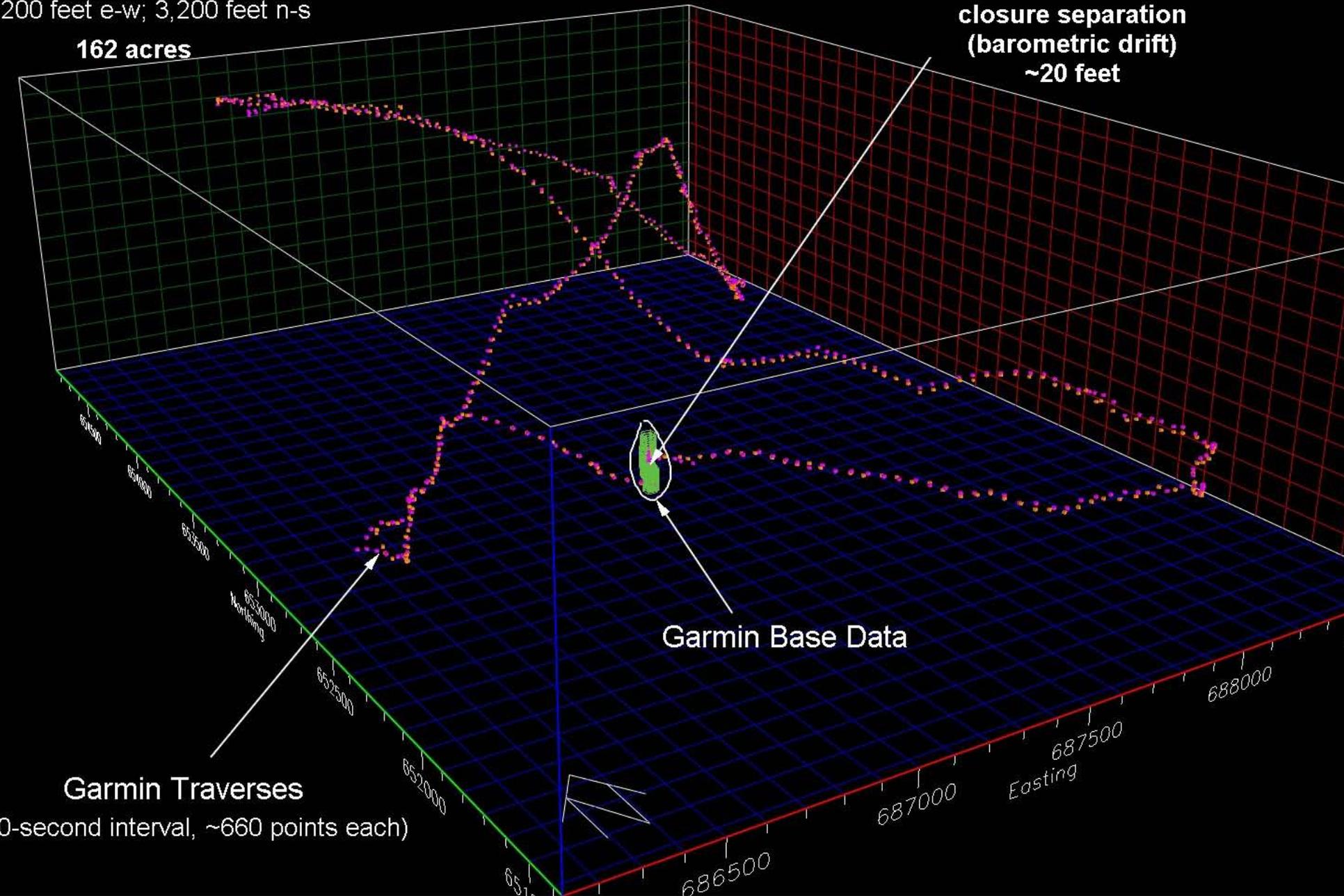


Maryland Mine

200 feet e-w; 3,200 feet n-s

162 acres

Traverse Start/End
closure separation
(barometric drift)
~20 feet



Garmin Traverses

0-second interval, ~660 points each)

Garmin Base Data

687000
687500
688000
Easting

653000
652500
652000
651500
Northing

Maryland Mine: 3 Garmins-one person "Survey" Results

Traverse Start/End
closure separation
(barometric drift)
~20 feet

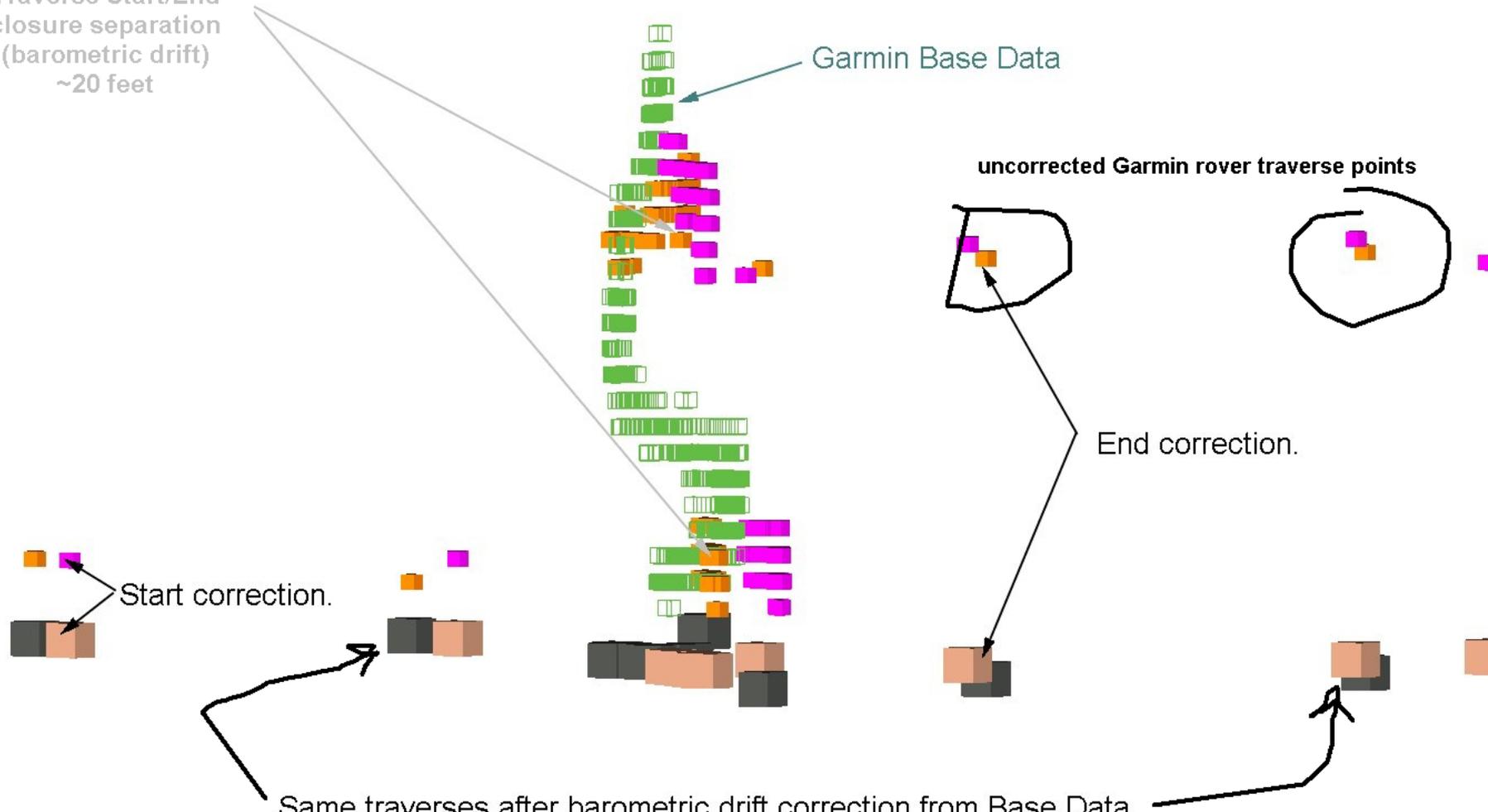
Garmin Base Data

uncorrected Garmin rover traverse points

End correction.

Start correction.

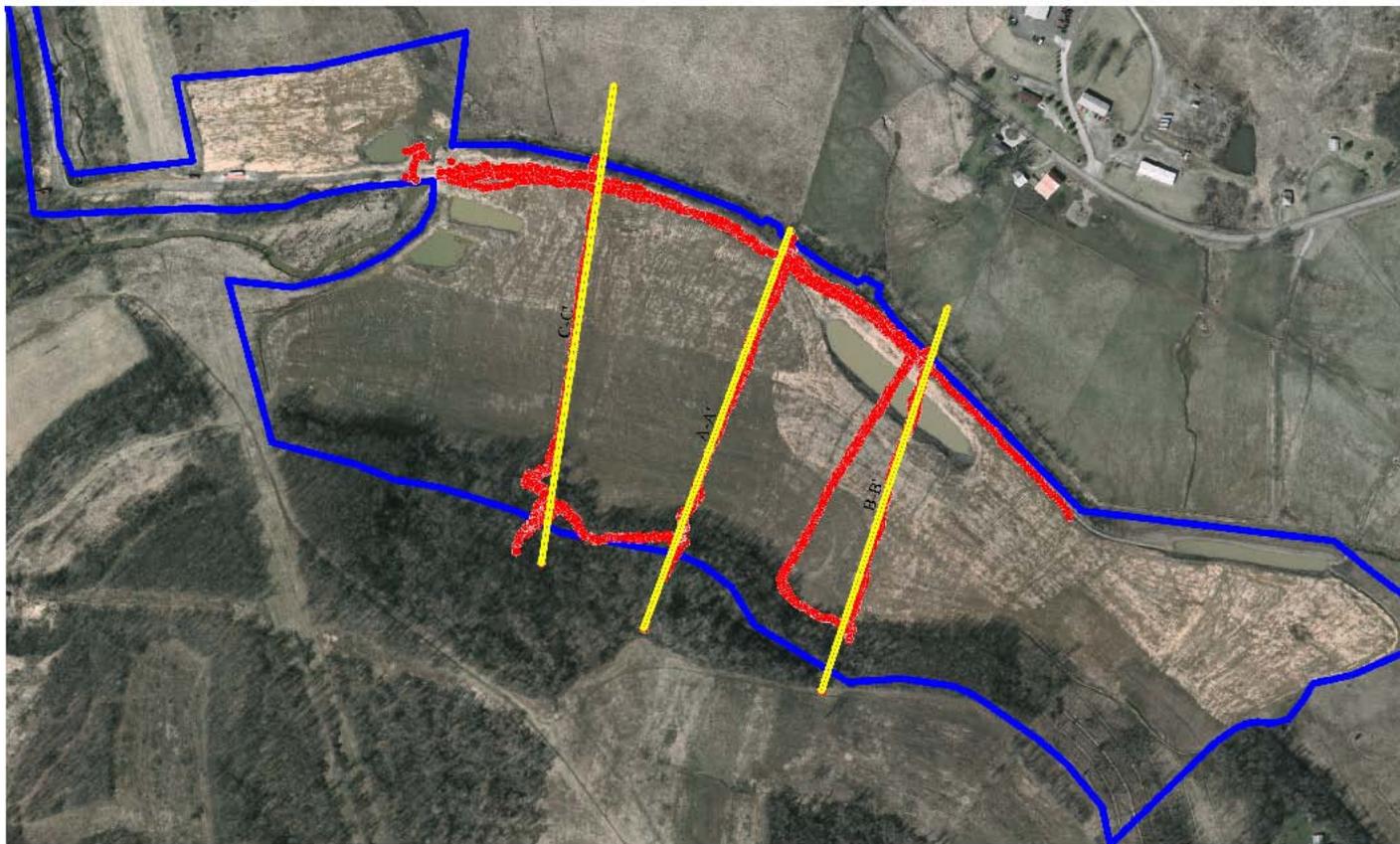
Same traverses after barometric drift correction from Base Data.
(includes 3.4' carry height correction)



How Does this Approach Compare?

- Another crew (Stefanie Self and Dave Agnor) used the base/rover Garmin approach on 3 Ohio mines:
- Full proof-of-concept resulted

Cravat D-2228 on 2007 OSIP Aerial



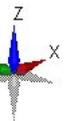
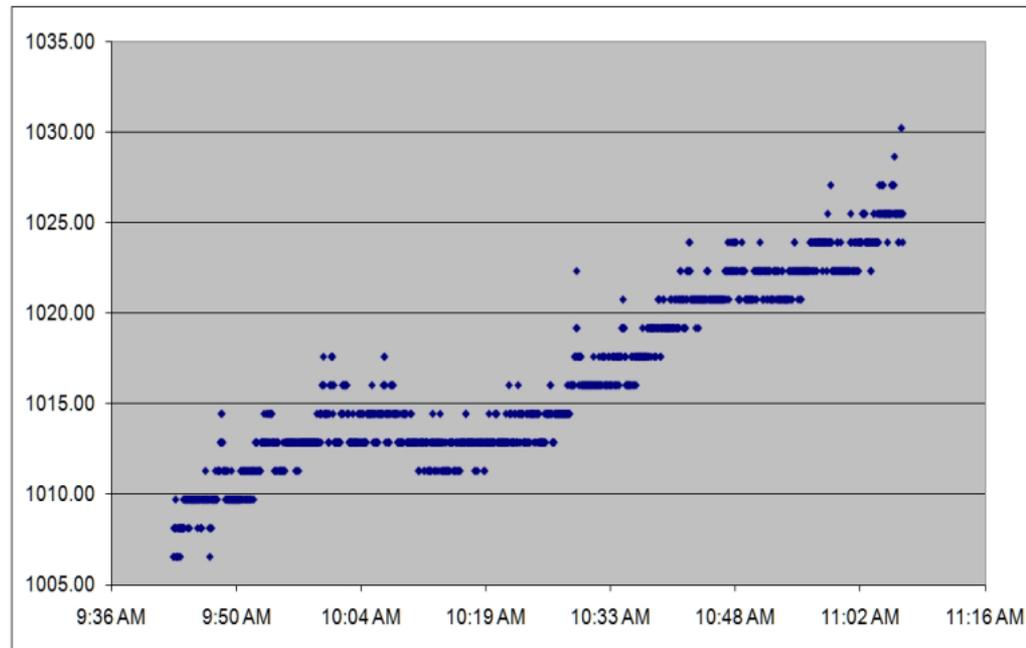
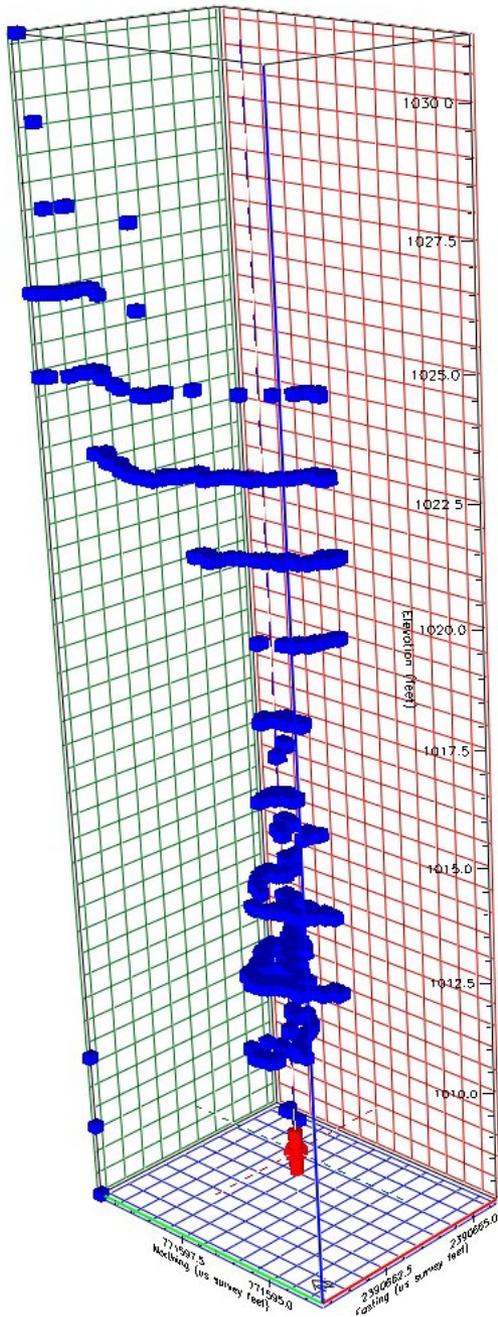
Permit=Blue; Sections=Yellow; GPS=Red

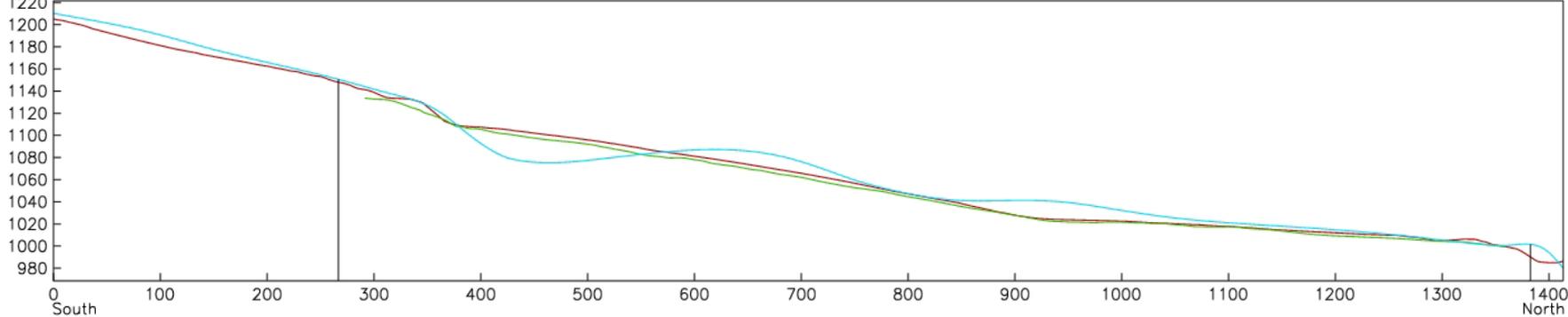
Cravat 2228 Garmin Base Data:

1,778 track points that fit into
a data range that is:

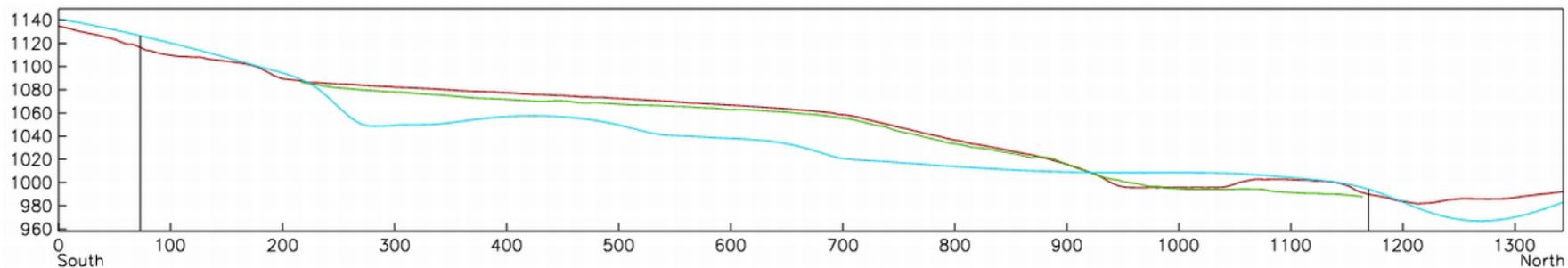
5 feet in X direction
6.5 feet in Y direction
and 24 feet in Z direction.

X,Y are from WAAS GPS
Z is from built-in aneroid altimeter:

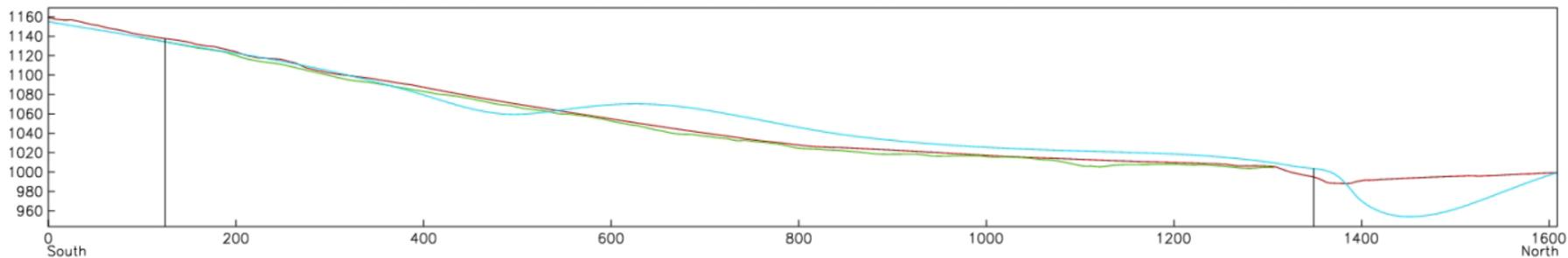




Cravat 2228 Section B-B' CAD Premine=Cyan; LiDAR Postmine=Red; GPS (Garmin) Postmine=Green

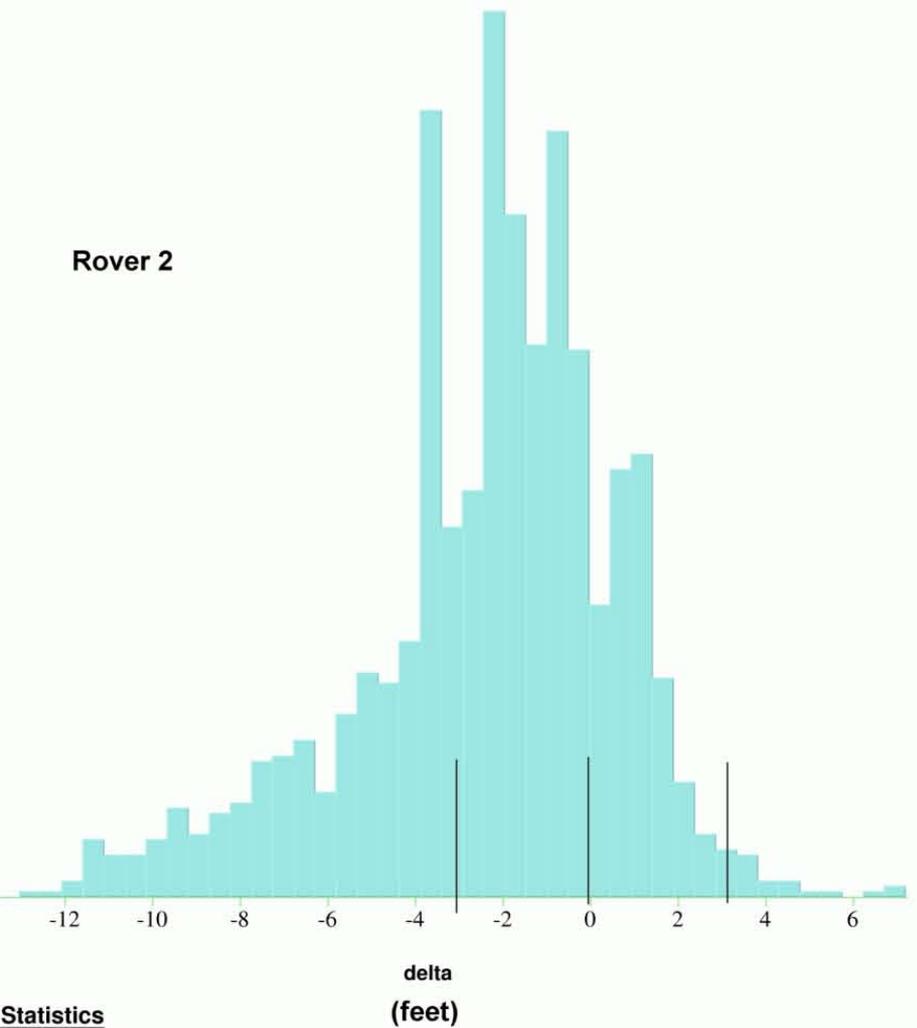


Cravat 2228 Section C-C' CAD Premine=Cyan; LiDAR Postmine=Red; GPS (Garmin) Postmine=Green



Avat Mine - Distribution of Difference Between Corrected Garmin Traverse Points and LiDAR Topography

Rover 2



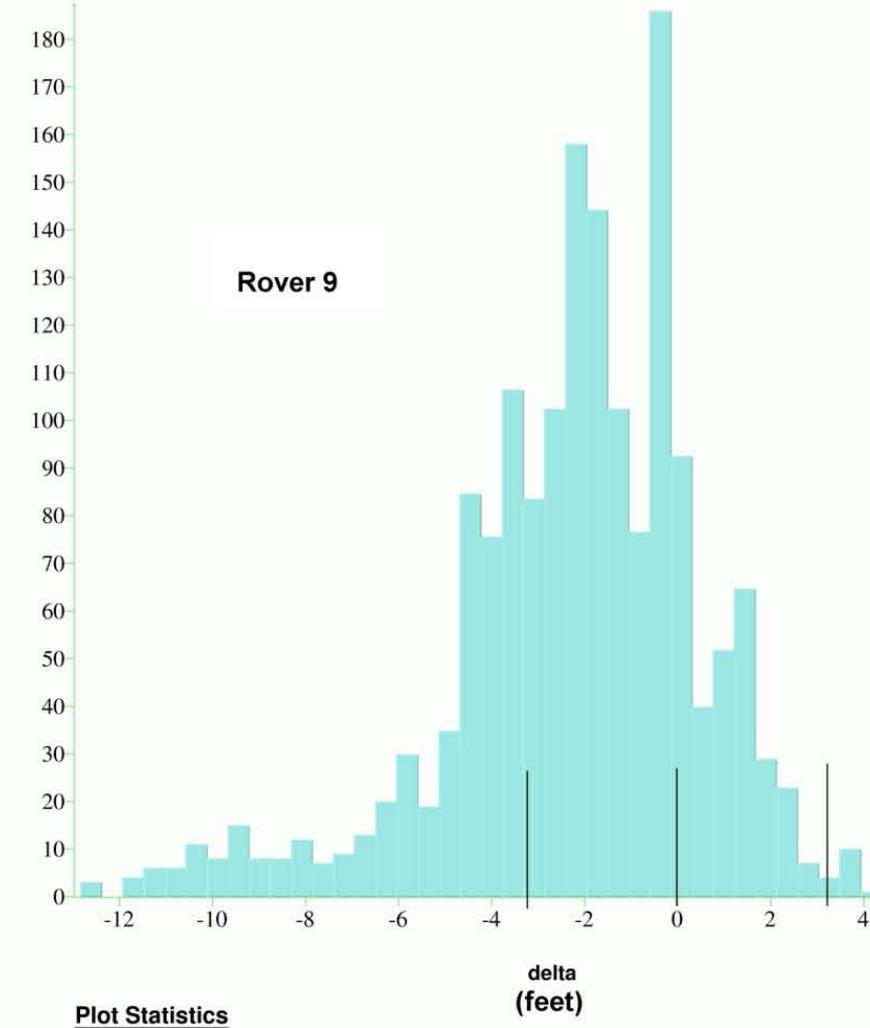
delta
(feet)

Statistics

Number of Data: 1664	Number of Nulls: 0
Mean: -2.4305	Standard Deviation: 3.0179
Variance: 9.1078	Coefficient of Variation: -1.2417
Maximum: 7.1853	Upper Quartile: -0.47966
Median: -2.0456	Lower Quartile: -3.693
Minimum: -14.615	Skewness: -0.74728
Kurtosis: 0.83553	

Frequency

Rover 9



delta
(feet)

Plot Statistics

Number of Data: 1671	Number of Nulls: 0
Mean: -2.2362	Standard Deviation: 2.7749
Variance: 7.7	Coefficient of Variation: -1.2409
Maximum: 7.5602	Upper Quartile: -0.4454
Median: -1.9623	Lower Quartile: -3.6902
Minimum: -12.962	Skewness: -0.79101
Kurtosis: 1.5825	

Conclusion

- While not survey-grade or sub-meter, this ***Innovation*** is easy, accurate, inexpensive, FAST, and was done with existing TIPS software and hardware.
- The AR AOC assignment could not have been completed without Garmin eTrex Vista GPS units.